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ABSTRACT

This paper outlines a set of procedures for designing a science program for students at the junior high school level. A flow chart provides an overview of the curriculum design, and brief notes are given to clarify the procedures to be taken at each stage on the chart. Programs designed in this manner should fit into a larger framework of science offerings carefully planned for grades K-14, and should contribute to the principal purpose of science education by developing scientific literacy in future citizens. Six components basic to scientific literacy are listed. In designing a science curriculum, it is suggested that the five approaches outlined by the Ontario Ministry of Education should be considered. These approaches provide structure to the course according to: (1) the discipline, (2) conceptual schemes, (3) domains, (4) themes, and (5) processes of science. Examples of the conceptual schemes approach, the domain approach, and the theme approach are discussed in some detail, and in each case flow charts are provided to illustrate the procedural steps in structuring a science unit. (JR)

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CREATIVE SYNTHESIS

Designing a Junior High School Science Program

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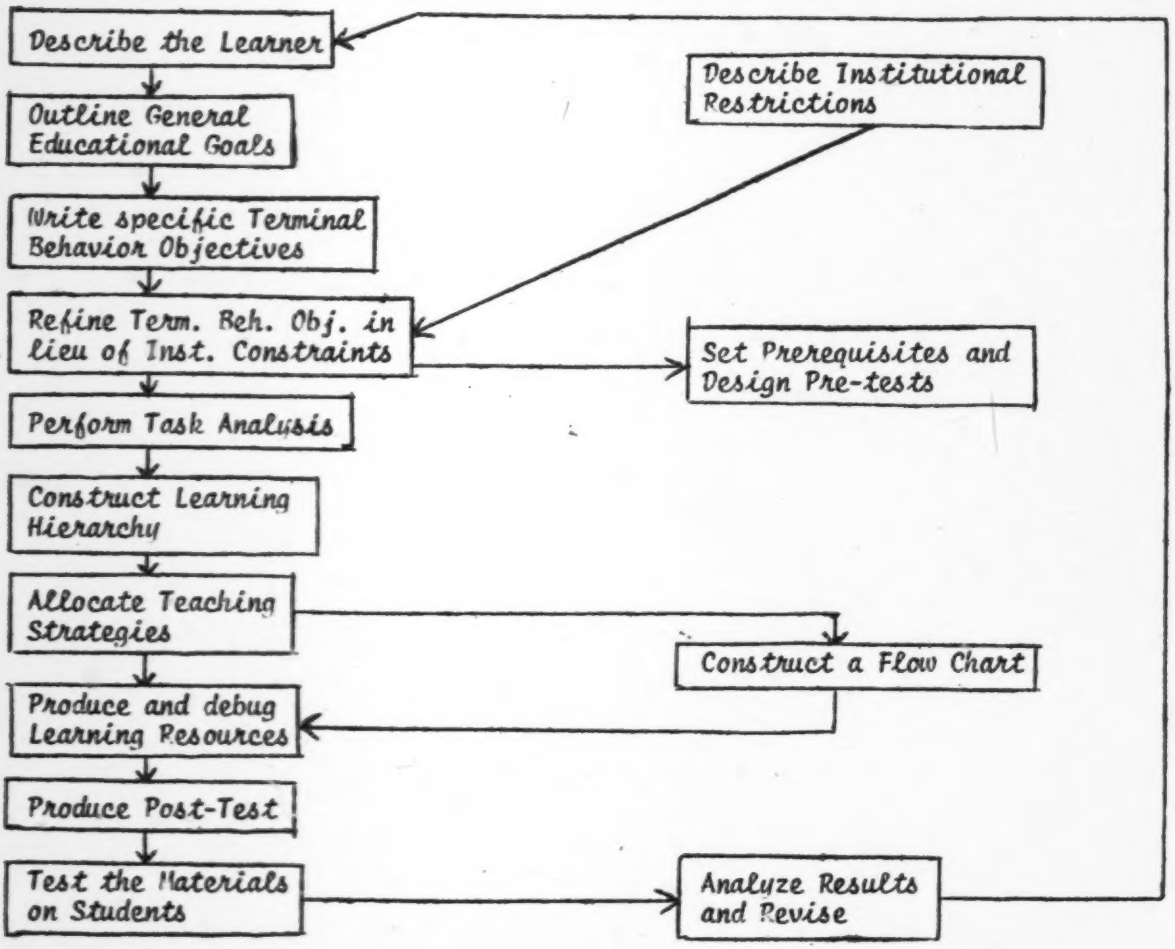
Designing your own science program for students at the junior high school level is a difficult but rewarding task. Many factors need to be taken into consideration when designing such a program. One approach which attempts to take many of these factors into consideration is summarized below.

AN APPROACH TO CURRICULUM DESIGN


Describe the Learner
Outline General Educational Goals
Write specific Terminal Behavior Objectives
Refine Term. Beh. Obj. in lieu of Inst. Constraints
Perform Task Analysis
Construct Learning Hierarchy
Allocate Teaching Strategies
Produce and debug Learning Resources
Produce Post-Test
Test the Materials on Students
Describe Institutional Restrictions
Set Prerequisites and Design Pre-tests
Construct a Flow Chart
Analyze Results and Revise

Describe the Learner

Describe the age range, stage(s) of intellectual development, home background, community background, etc. (Study Piaget's Stages of Intellectual Development and Gagne's, Bruner's and Ausubel's ideas.)

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Describe Institutional Restrictions

Determine the financial, time, space and local resource restrictions.

Outline the General Educational Goals

Describe the immediate and future needs of the student and the future needs of society. Important rather than trivial goals should be stated. If these goals are written with the next area of study in mind, they will be more relevant. At this stage the description of the goals need not be written in terms of the specific terminal behaviours.

Write Specific Terminal Behavioral Objectives

The specific terminal behavioral objectives must specify the desired performance in a measurable way. The desired concepts, conceptual schemes, processes, psychomotor skills, and attitudes should be specified. (Read articles describing these. Study Bloom's Taxonomy which describes the cognitive, affective and psychomotor domains in Testing and Evaluation for the Sciences by Hedges. Also become familiar with the preparation and use of instructional objectives by reading Preparing Instructional Objectives by Robert F. Mager.

Refine the Terminal Objectives

Modify the terminal behavioral objectives as restricted by the institutional constraints.

Set Entering Prerequisites

Design pre-tests to determine which of these have been met by the students. The test will determine if the students have the concepts, processes and motor skills to handle the curriculum or if they have already achieved a significant number of the objectives.

Perform Task Analysis

The task analysis enables the curriculum designer to determine intermediate instructional objectives relating to each terminal behavioral objective. One usually successful method is to analyze each behavioral objective separating it into a hierarchy of intermediate objectives by successively asking the question - What must the learner be able to do to perform the higher order objectives given only instructions? (Read articles and books dealing with Task Analysis - see Gagne.)

Construct the Learning Hierarchy

After the learning hierarchy has been constructed as indicated above, the attributes of the learner that may interact with the instructional method to be used at each level should be listed.

Allocate Teaching Strategies

The teaching strategy or strategies to be used at each level of the hierarchy should be indicated. A variety of teaching strategies is important. A partial list is given below.

- outdoor education (field trips)
- discussion (pairs, small & large groups)
- investigations (guide sheets) - alone, pairs, small groups
- examination of specimens (guide sheets) - alone, pairs
- student presentations - alone, pairs
- use of A-V aids and resource centre - alone, pairs
- interdisciplinary problem solving
- film lesson
- model building
- games
- seminars
- demonstrations
- debates
- essays
- lecture
- socratic lessons
- community contacts

Students and teachers should use the teaching strategies which are best suited to themselves and the nature of the material.

Construct a Flow Chart

If the curriculum is to be individualized a flow chart should be constructed designating the path or paths the learner may follow.

Produce and Debug Learning Resources

Films, film loops, equipment, experiments, outdoor education sites, games, reading articles, guide sheets, etc.

Produce Post-Test or Examinations or other Evaluation Devices

Care must be taken that these tests are designed to test the instructional terminal behavioral objectives set down earlier.

Test the Materials on Students and Evaluate

Revise the Materials in terms of the Evaluation Results

The modern trend in science education is aimed at developing scientific literacy in future citizens. The American Association for the Advancement of Science summarized this aim very well in an article titled "Trends in Science Education" in the December 1972 issue of Science Education News. They state: "The principal purpose of science education programs in grades K-14 is the development of scientific literacy in future citizens." Educational journals make frequent reference to this aim as well. The NSTA has produced a working paper on scientific literacy.

What constitutes scientific literacy? There are six components basic to scientific literacy:

1. an understanding of the interaction between science and society
2. an understanding of the ethics that control the scientist and his work
3. an understanding of the nature of science
4. a functional understanding of the conceptual knowledge of several different sciences
5. an understanding of the differences and interrelationships of science and technology
6. an understanding of the interrelationships of science and the humanities

The challenge of developing science programs to accomplish all of these objectives over a 14 year period is formidable but must be met if future graduates are to better understand the complex technological society of today and tomorrow.

The teacher, school or school district that is attempting to plan science courses along these lines must begin in a small way with a small increment. They can begin by developing units of work which fit into the overall framework. If the framework is carefully established and documented, teachers can work logically to develop the required learning resources. There are several approaches to Unit Planning.

APPROACHES TO CURRICULUM SYNTHESIS

The Intermediate Division Interim Revision 1972 Science guideline from the Ontario Ministry of Education outlines five approaches that can be used by the teachers at the Intermediate Division to provide structure for their courses. These are:

(a) the discipline of biology, chemistry, geology, physics, etc.
(b) the conceptual schemes of science such as "all interacting units of matter tend towards equilibrium states in which the energy content is a minimum."
(c) domains such as ponds, hardware stores, bicycles
(d) themes such as Pollution, Growth and Development, Ecology
(e) processes of science such as observing, classifying, recording data, formulating models, etc.

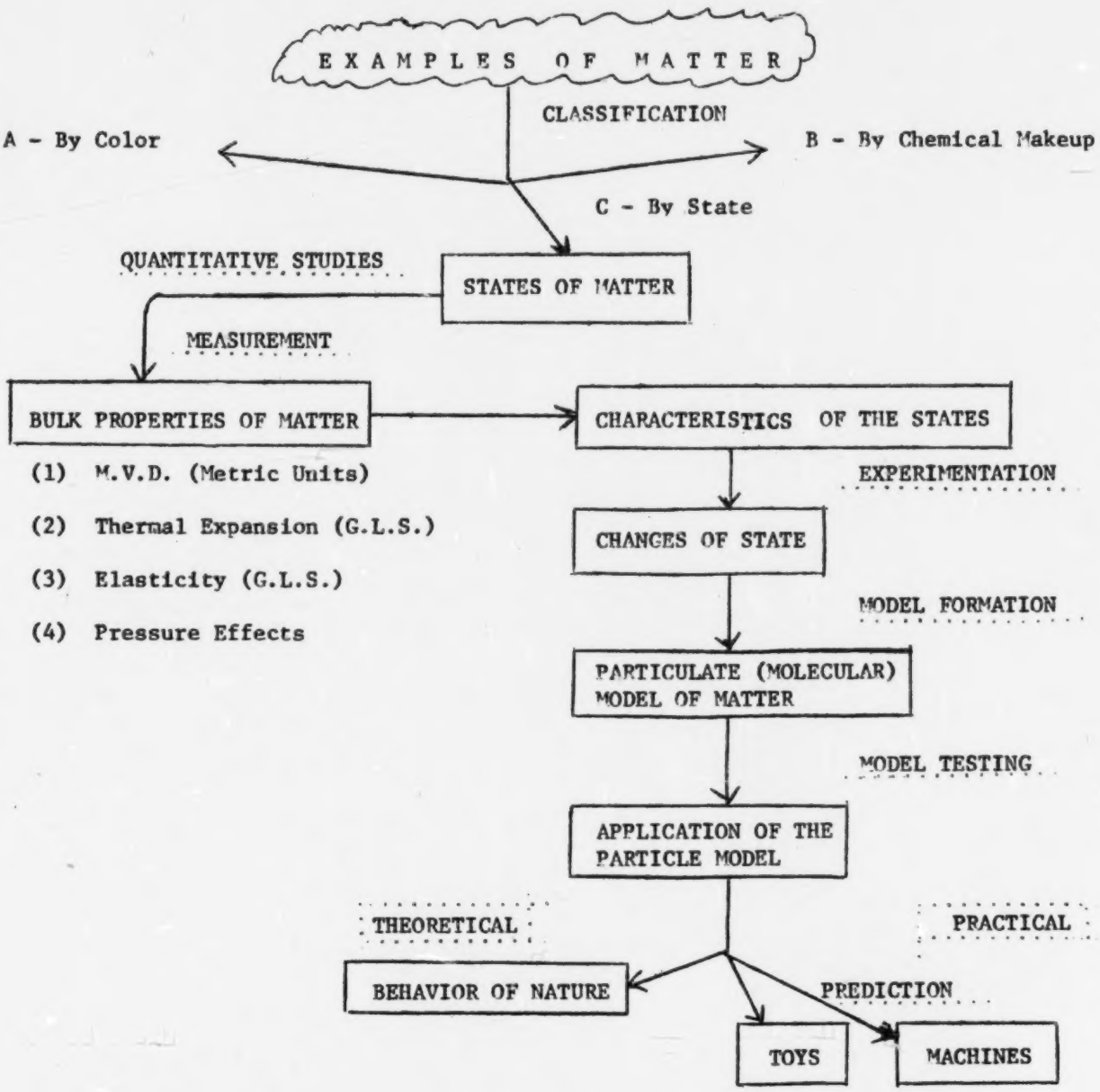
Three of these approaches will be described.

A CONCEPTUAL SCHEMES APPROACH

The teacher using this approach to unit planning selects learning experiences necessary for an understanding of one or more big ideas or conceptual schemes of science. The NSTA Conceptual Schemes or the BSCS themes can serve as starting points. A task analysis is performed to determine the number and order of the concepts that can be organized into a logical learning hierarchy. A flow chart indicating one way of structuring a unit inquiring into the conceptual scheme "The Particulate (Molecular) Model of Matter" is outlined below.

FLOW CHART

THE MOLECULAR MODEL OF MATTER



A DOMAIN APPROACH

The teacher using this approach selects learning experiences to integrate knowledge about a particular area of interest. The topic chosen should lend itself to an activity-centered approach if it is to incorporate the inquiry philosophy. The strength of the domain-centered unit lies in the opportunity to integrate knowledge from many traditional disciplines. The teacher using this approach incorporates 8 basic planning steps. These steps are illustrated using the bicycle as the domain.

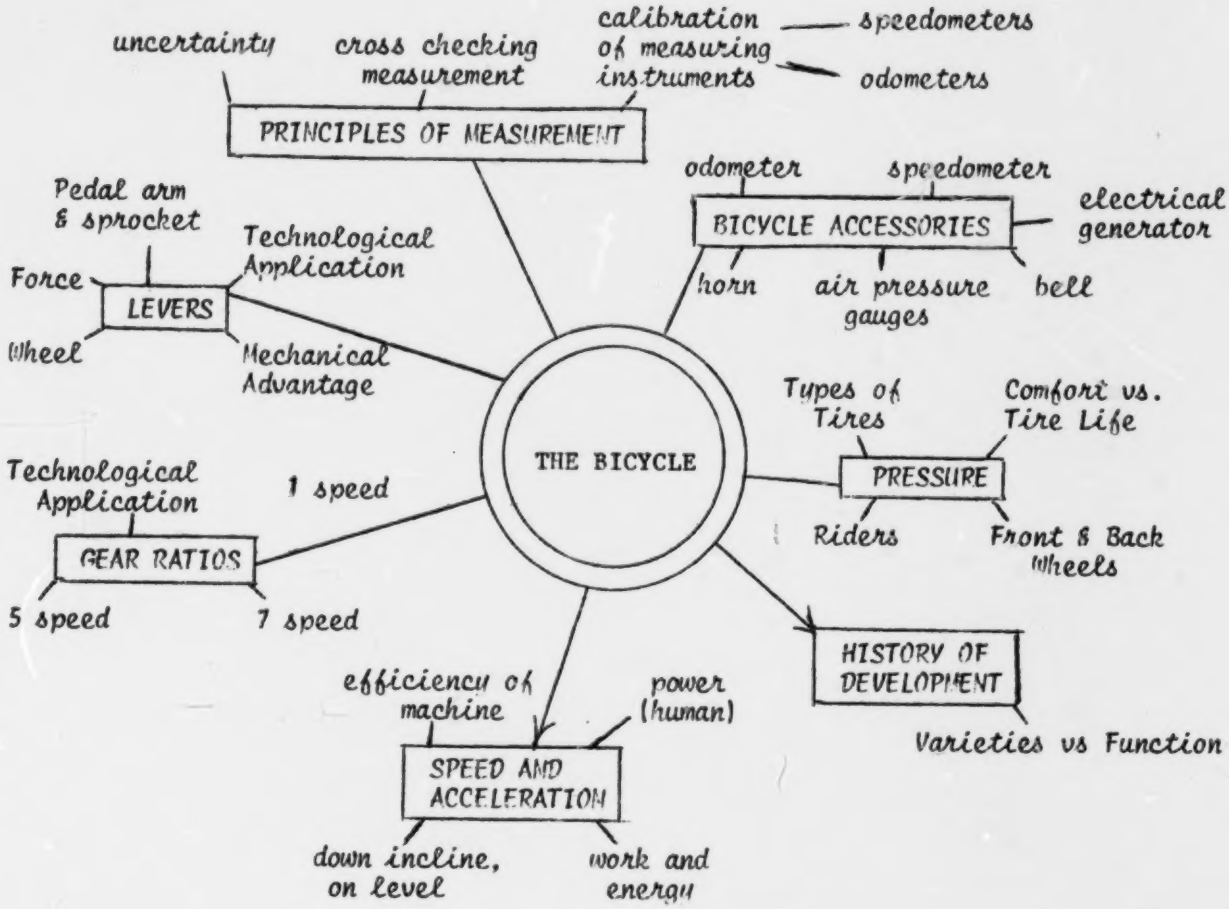
Step 1 - Select a Domain

Select a topic or area of study which is interesting to students, is accessible, and lends itself to a 'doing' type of inquiry. The bicycle is an ideal domain to use since:

(1) a good selection of bicycles is available
(2) many accessories are available
(3) many investigations can be performed in the classroom using the bicycle as lab apparatus
(4) the investigations can be incorporated into the development of a conceptual scheme of science such as: "Energy is neither created nor destroyed but is converted from one form to another without loss."
(5) students know very little about the history, physics or technological development of the bicycle and may be interested in finding out more
(6) students can be given the opportunity to use the processes of scientific inquiry to study various concepts related to the bicycle

Step 2 - Brainstorming

Before presenting the domain to the students the teacher should brainstorm and construct a flow chart which surveys the number and variety of problems that students wish to investigate. An example flow chart for the domain "The Bicycle" is outlined below.



As you can see, this topic lends itself to a large number of quantitative and qualitative studies directly related to science. One could compile an extensive chart for the history of its development and the uses to which it is put.

After the teacher has brainstormed to determine the suitability of the topic, a list of questions for investigation should be compiled with the students. The list should reflect the activities that are of interest to the pupils. A suggested plan of attack and some questions are outlined below.

(1) Begin by asking the pupils to suggest activities that they could do using the bicycle to find out more about it. Stress that the pupil's suggestions must be things to do, that these activities must be suited to investigations largely within the area of the school (building, grounds). Record their suggestions for future reference and use.

(2) Have the pupils examine as wide a variety of bicycles and accessories as possible. When the students have looked at these materials and handled them, ask for more suggestions and add these to the list.

(3) The first step in the brainstorming occurs when the teacher adds to the list suggestions from the initial planning that the students have overlooked.

A summary based on the chart is included below.

Principles of measurement - uncertainty, cross-checking of measurements, calibration of measuring instruments, e.g. speedometers and odometers.

Levers - the understanding of the pedal arm and sprocket as levers. Calculation and checking by measurement of what force is exerted on the road to propel the bicycle forward when a certain force is applied at right angles to the pedal arm.

Gear Ratios - the relationship between number of revolutions of the pedal and number of revolutions of the wheel for different combinations of gear ratios.

Speed and Acceleration - use of pendulum, metronome, stop watches and paper tape timers as timing devices to make measurements of speed and acceleration.

Pressure on surface - calculation of the pressure exerted by the tire on the road for different types of tires and also when persons of different weight sit on the bicycle. Comparison of the force on the road exerted by the front and back wheels. Variations of the pressures on the road for different air pressures in the tires. These can have significance in riding on soft surfaces.

Air pressure in the tires - what air pressure is needed in the tires to maintain the rim in a fixed height above the road for different weight of people sitting on the bicycle seat. A study of whether or not it is harder to pedal with soft or hard tires. (This is a study of rolling friction.) An investigation of the variations of the air pressure inside the tire when no one is sitting on the bicycle and the difference with various weights of people sitting on the bicycle. This is a good example of a new situation in which a student can make an hypothesis and try to give reasons for it and check the truth of it by measurement.

Step 3 - Forming Groups

Refer the students to the list of suggestions developed in Step 2 and encourage them to select the particular activity that they would like to investigate. Some activities may not be selected. Some students may wish to work on an investigation all by themselves. A group of two students is usually an ideal size.

The names of the students involved with a particular activity should be recorded beside the appropriate activity right on the list. This will aid the teacher in keeping track of the activities of each student.

Step 4 - Student Planning

When groups have been established, each group should be encouraged to make the following decisions for their activity:

(1) What will we need to do the activity?
(2) Where can we obtain the materials?
(3) How will we use the materials?
(4) What will each of us do?
(5) How will we record what we find out?
(6) How will we display what we find?

The teacher should discuss each group's plans with the group members. This can be done with one group at a time while the remainder of the class is working on their activity. At this stage the teacher may wish to guide the students by asking such questions as:

(1) Did you make any predictions before beginning?
(2) Are you taking any measurements?
(3) Are you taking enough trials to rule out chance?
(4) Should you take an average?
(5) Would it help if you plot a histogram or a graph?
(6) Do you have a control for purposes of comparison?
(7) How many variables are being changed at one time?

Other aspects of the processes of scientific inquiry that are applicable but that would not normally occur to students should be raised. Alternatives regarding safety and practicality may also need to be recommended.

Step 5 - Carrying out the Investigation

The students should now be ready to carry out their investigation working largely on their own. The teacher's function is to pose questions and provide assistance or guidance when an activity bogs down.

Some activities may require modifications but much learning occurs through a trial and error approach. The room will be noisy, messy and seething with movement. The teacher should be able however to gain the students' attention, if necessary, by using some prearranged signal.

The pupils should be encouraged to collect their data on rough paper as they work. The activity should not be considered complete until the data has been used to discuss the problem being investigated and until some answers have been reached for the problems under investigation.

If the activities are being performed outside the school, all necessary safety precautions must be taken.

Step 6 - Displaying the Results

The students should be encouraged to translate their rough work into a finished product using whatever media and recording technique they believe to be the most appropriate: i.e. graphs, charts, paragraphs, diagrams, tape recordings, overhead projector transparencies, and so on.

Since the emphasis in recording is on developing their ability to communicate, the final result should be large, brief, colorful and more accurate than the rough work.

Step 7 - Capitalizing on the Results

This step, although one of the most important, is most often neglected. The teacher should select the work displayed and presented by a particular group of students for peer group evaluation in a discussion. The work chosen may contain an important concept or might be used to reinforce a technique or skill previously taught and should be of value to the entire class. The discussion might lead to the correction of an error.

Step 8 - Adding to the List

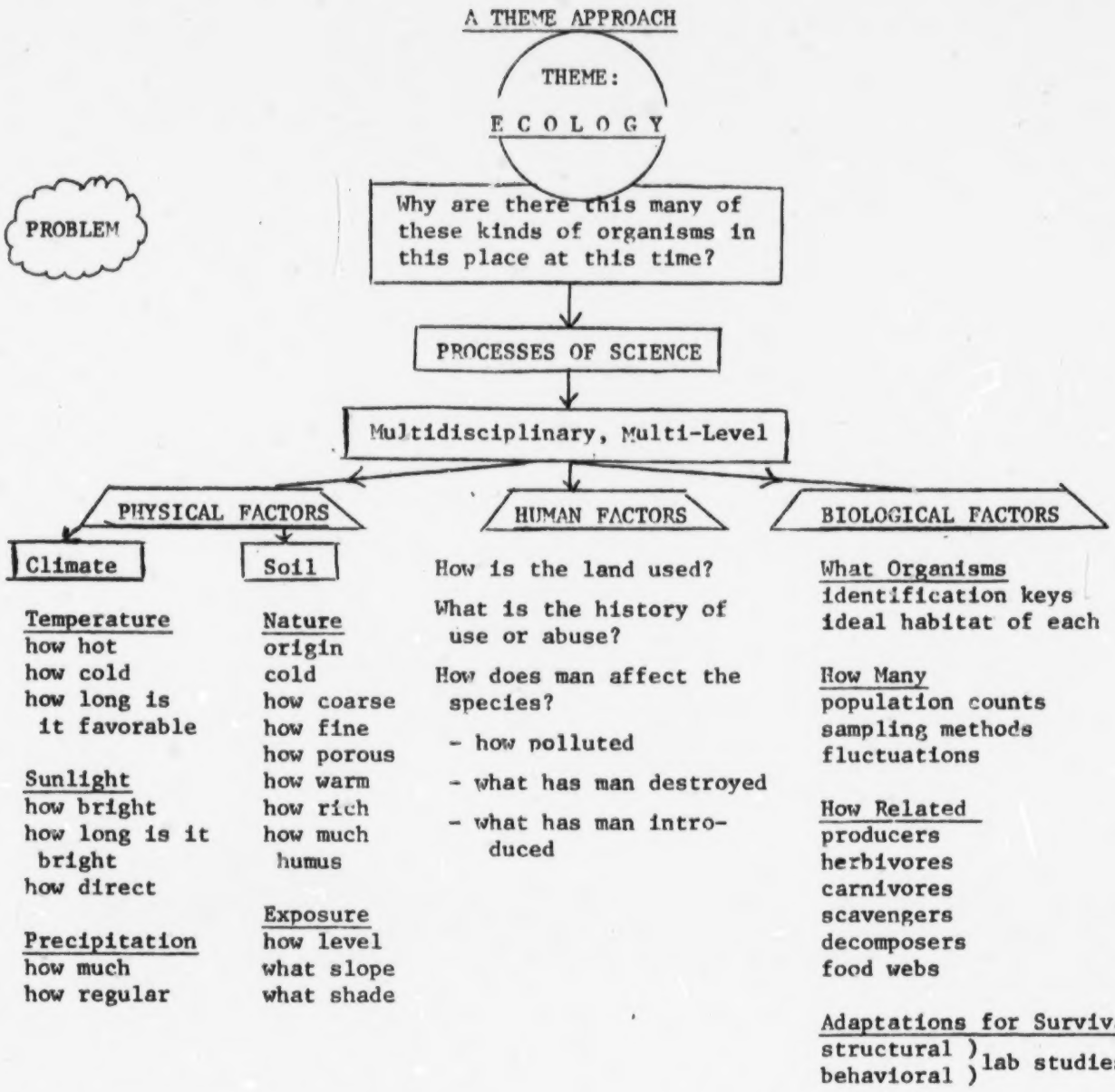
When a group of students has completed its initial investigation they are ready to move on to another activity. This activity may arise from the investigation completed by the group. The new suggestions should be added to the original list. New groups of students will form as new interests are selected. The activities added to the list may spread further and further out from the original topic.

The teacher may wish to terminate the study of the topic when the activities become too diversified or when the students' interest falls.

A THEME APPROACH

Themes can provide the element of structure for various increments of time. Themes give the knowledge gained during the study a much greater relevance than is developed through a subject discipline organization. Information from many fields of science and other areas may be called upon in the study of a theme. The thematic approach brings together factual information and underlying concepts in a unique relationship as the study of the theme threads its way across traditional boundaries of organizational patterns.

The eight steps described in the Domain Approach apply equally as well to the Theme Approach. A flow chart for the theme "Ecology" is illustrated below.


A THEME APPROACH
THEME:
E C O L O G Y
PROBLEM
Why are there this many of these kinds of organisms in this place at this time?
PROCESSES OF SCIENCE
Multidisciplinary, Multi-Level
PHYSICAL FACTORS
HUMAN FACTORS
BIOLOGICAL FACTORS
Climate
Soil
Temperature
how hot
how cold
how long is it favorable
Sunlight
how bright
how long is it bright
how direct
Precipitation
how much
how regular
Nature
origin
cold
how coarse
how fine
how porous
how warm
how rich
how much humus
Exposure
how level
what slope
what shade
How is the land used?
What is the history of use or abuse?
How does man affect the species?
- how polluted
- what has man destroyed
- what has man introduced
What Organisms
identification keys
ideal habitat of each
How Many
population counts
sampling methods
fluctuations
How Related
producers
herbivores
carnivores
scavengers
decomposers
food webs
Adaptations for Survival
structural)
behavioral) lab studies